

Semi-Annual Report  
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A. Task Objective: Continued Algorithm Development for Global Mapping of Phycoerythrin Pigment, Dissolved Organic Matter, and Chlorophyllous Pigment

1. MODIS North Atlantic Test Site Establishment and Characterization

As previously reported, the MODIS North Atlantic Test Site has now been firmly established as originally proposed. The Test Site includes the New York Bight/Mid-Atlantic Bight/Gulf Stream/Sargasso Sea and is conveniently located north and east of GSFC/WFF. Characterization has been initiated by ship sampling, aircraft overflights, and analysis of historical data available from within the NASA AOL project since 1980. Much of the data obtained in the northwestern portion of the test site will be used for algorithm development in Case 2 waters. Active-passive ocean color data from 1984-1992 are being screened for suitable application to algorithm development.

2. Selection of Case 1 Data Sets

Airborne active-passive ocean color data acquired within Case 1 oceanic regions with the NASA Airborne Oceanographic Lidar is now being screened for use in algorithm development. Several promising candidate data sets have been identified. In particular, the JGOFS North Atlantic Bloom Experiment (NABE) and the adjunct Iceland Faeroe Frontal Region data set taken south and southeast of Iceland are found to be of high quality. Screening of other data sets continues.

B. Work Accomplished

1. In Situ Optical Characterization of the MODIS North Atlantic Test Site.

As previously reported, the in situ characterization of the test site was initiated on February 28, 1991 with the acquisition of surface layer grab-samples during the Surface Wave Dynamics Experiment (SWADE). Through the cooperation of Dr. Charles Flagg arrangements were made to collect 20 samples along an in-bound track line from the Gulf Stream to the mouth of the Delaware Bay. The samples were filtered (0.45  $\mu$ m) to remove scatterers and absorbers other than the dissolved organic matter (DOM). The spectral absorbance of the filtered samples was measured at Wallops, Cornell Laboratory for Environmental Remote Sensing (CLEARS), and Woods Hole Oceanographic Institute. Spectral fluorescence of the filtered samples was also measured at CLEARS (Dr. Tony Vodacek, now a NRC Resident Research Associate at

Wallops) and WHOI (Dr. Niel Blough). The results of the analysis of this data are being used in a manuscript describing the distribution of the fluorescence of dissolved organic matter in the Pacific and Atlantic Oceans.

Recovery of the absorption coefficients for the light-absorbing or chromophoric components of the dissolved organic matter (aCDOM) from their fluorescence emission has been investigated by laboratory analyses of the surface samples gathered from the Feb. 28, 1991 cruise. These absorbance and fluorescence analyses, (and work reported by others), suggest that absorption coefficients in the near ultraviolet can be directly retrieved from measurements of the fluorescence emission of CDOM. Thus, absorption coefficients in the visible can potentially be obtained from the empirical observation that CDOM absorption is exponentially related to wavelength. The errors in the laboratory fluorescence measurements were minimized through the combined use of the water Raman scatter as an internal radiometric standard and quinine sulfate as a reference. Thus, aCDOM algorithm retrieval errors are primarily attributable to the use of commercial spectrophotometers having maximum optical pathlengths of 10 cm. Use of emerging technologies, such as the long-path reflecting tube absorption meter and the integrating cavity absorption meter, are suggested for future improvements to aCDOM retrieval algorithms. While the aCDOM retrieval appears feasible, the relationship to CDOM emission is susceptible to changes in fluorescence yield, so the continued temporal study of marine samples from many diverse oceanic locations is needed. When applied to shipboard and aircraft laser fluorometers, this retrieval methodology and the resulting DOM absorption coefficients will be used in ocean color models and associated satellite sensor/algorithm developments directly aimed at phycoerythrin retrieval. The DOM is important since it is a major interferant to the detection and quantification of chlorophyll and chlorophyll accessory pigments (CAP) such as phycoerythrin. Likewise, it is a contributor to the carbon cycle itself. A manuscript titled: "Inherent Optical Properties of the Ocean: Retrieval of the Absorption Coefficient of Chromophoric Dissolved Organic Matter from Fluorescence Measurements" is now "in press" (L&O) based on the fluorescence/absorption work to date.

## 2. In-situ and Airborne Optical Characterization of MODIS North Atlantic Test Site.

Through the cooperation of Dr. George Luther of the University of Delaware, 9 additional filtered and 9 unfiltered samples were gathered during a cruise of the Research Vessel Cape Henlopen on March 4, 1992. An overflight of the vessel was conducted on March 4, 1992. The purposes of this flight were to (1) calibrate the DOM fluorescence to water-Raman ratio [ $F(450)/R(401)$ ] and to (2) provide a cross-shelf reconnaissance survey of the team member's MODIS North Atlantic Test Site during a periods not covered by historic AOL missions. The preliminary results indicated a surprising amount of phycoerythrin-bearing organisms already present in early March. Past flight historical experience

has shown that the phycoerythrin-containing phytoplankton tend to have maximum numbers during late March to early April. The ship samples will be used to complement the previous samples and data base to improve the accuracy of the resulting algorithm(s).

3. Participated with the Airborne Oceanographic Lidar in the JGOFS Central Equatorial Pacific Study (EQPAC) during August 1993. Considerable Case 1 ocean color data was obtained during the JGOFS flights along the -140W longitude and the several equator crossings in transit to Christmas Island for aircraft refueling. The equator crossings also provided data for the study of a highly concentrated chlorophyll patch observed just north of the equator. Ship truth was taken concurrently.

At the conclusion of the JGOFS missions, flights were conducted in Monterey Bay in conjunction with scientists from the Monterey Bay Aquarium and Research Institute (MBARI), NOAA, and Woods Hole Oceanographic Institution. The MBARI vessel was used by their scientists and scientists from NASA and Woods Hole to collect truth data along the flight tracks executed on September 4, and 5, 1993. One of the scientists was Interdisciplinary Team Member, Dr. Niel Blough. One of the prime objectives of this cruise was to obtain additional in situ ocean color data to address the CDOM algorithm development. Excellent airborne active-passive data were obtained for use in our algorithm development as well. Some phycoerythrin pigment fluorescence was observed with the AOL and concentration values are awaited. A workshop is to be held on Feb 18-19, 1993 to discuss the data.

4. Participated with the Airborne Oceanographic Lidar in Dr. Kendall Carder's TAMBEX II cruise of the Suncoaster in the Gulf of Mexico during the week of May 11, 1992. (Note that Dr. Carder is both a MODIS and a HIRIS Science Team Member). One of the prime objectives of this cruise was to obtain the necessary in situ ocean color data to address the CDOM algorithm development of Dr. Carder. Excellent airborne active-passive data were obtained for use in our own algorithm development as well. No significant phycoerythrin pigment fluorescence was observed with the AOL in the Gulf of Mexico, so no pigment extractions were attempted using the shipboard filtered samples.

#### D. Anticipated Activities During Next Half Year.

##### 1. Phycoerythrin Algorithm Development Activities

Plans call for us to again directly address the quantification of the phycoerythrin signal as outlined in our own MODIS proposal. Since the AOL flights over the TAMBEX cruise in the Gulf of Mexico showed insufficient amounts of phycoerythrin. Other options must be addressed. These include the Monterey Bay flights in September, 1992 that showed the pigment to be present. Also, ship samples were taken that should allow the pigment to be quantified. Dr. Dan Repeta of Woods Hole will be participating in the pigment analyses. First-time ship calibration of the airborne phycoerythrin-to-water Raman signal are the expected results of this field work. Truth samples for

phycoerythrin pigment are reportedly available from the EQPAC overflights. This will also be pursued next quarter.

## 2. Chlorophyll Pigment and CDOM Corrections to the Algorithm.

Major perturbations or influence to the ocean color spectrum are provided by chlorophyll and CDOM. These oceanic constituents significantly impede the retrieval of phycoerythrin pigment from the upwelled radiances. Accordingly, they must be dealt with in a systematic way in order to understand their effects and the impact on the retrieval of phycoerythrin and its ultimate quantification. In situ and airborne data gathered to date will be used to model the effects to ascertain the extent that they can be removed and/or quantified.

## 3. Flights of the NASA Airborne Oceanographic Lidar are planned for the lower portions of the MODIS Test Site during April, 1993 during the conduct of NSF's Land-Margins Ecological Research (LMER) studies related to the generation and fate of the Chesapeake Bay plume. Truth data will be gathered by scientists from the Horn Point Environmental Laboratory (HPEL) aboard the research vessel Cape Henlopen.

## 4. The lack of a 600nm band on MODIS-N remains the biggest problem facing the retrieval of the phycoerythrin pigment on the first sensor launch. Plans to synthesize a 600nm band from existing bands will be performance tested using data obtained over actual oceanic phycoerythrin pigment using the 32-band AOL passive ocean color subsystem (POCS).